Design of the FeatherSail-3 Satellite

Principal Investigator: Dean Alhorn **Mission Design**: Kevin Schillo **Structure & Mechanisms**: Josh Sandler **Avionics & Power**: Lonnie Labonte

Abstract

FeatherSail-3 is a 6U form factor CubeSat which will demonstrate the use of mechanically actuated sails for deorbiting space debris. Utilizing solar radiation pressure (SRP) for propulsion and attitude control frees the satellite from the constraints of requiring on-board fuel reserves. The fully deployed sail has an area of 40 m^2. The satellite mission will begin at an altitude of 525 km and the altitude will be raised to 650 km for rendezvous and capture of the FASTSAT-HSV01 satellite. After collapsing its sails around the target, the increased cross-sectional area will provide significant aerodynamic drag in order to quickly deorbit the target spacecraft.

Background/Design Heritage

NanoSail-D (NSD) was a 3U CubeSat launched in November 2010 which successfully deployed a solar sail in January 2011. The FeatherSail family of spacecraft was conceived as a successor to NanoSail-D to further the development of solar sail technology by using articulated sails to control spacecraft attitude and thrust. FeatherSail-3 (FS3) is based on designs for FeatherSail and FeatherSail-2, but has been designed in a smaller 6U CubeSat form factor. FeatherSail-3 will use boom spools, booms, and sails which are derived from those designed and flown on NanoSail-D.

Structure & Mechanisms

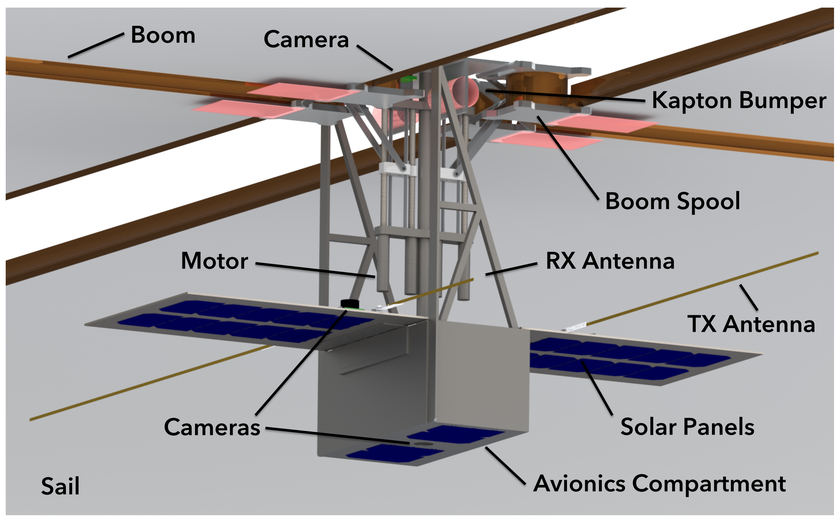

Figure 1: Close-up of FeatherSail-3 model with deployed sails.

Spacecraft Deployment: Planetary Systems Corp. 6U Canisterized Satellite Dispenser
Structure: 6061-T6 aluminum frame
Boom Spools: (4x) modular boom spools modified from NanoSail-D
Booms: (2x per spool) 4.47 m long, AFRL developed TRACv1 boom
Sails: (4x) 10 m^2 aluminized CP1 Polyimide reinforced with Kevlar thread
Sail Storage: z-fold technique, less than 100 cm^3 stored volume for all four sails
Sail Actuation: Crank-Slider mechanism driven by ¼-20 Acme lead screw. Boom spool deployment assisted by Kapton bumpers. Capable of 90° rotation in approximately 2.5 minutes.

Attitude Control

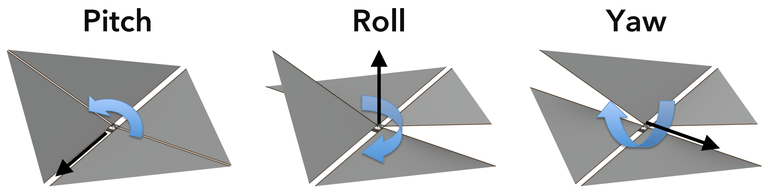

Figure 2: Attitude control maneuvers.

FeatherSail-3 is capable of attitude control in three axes by actuating four independent sail sections. Attitude changes are used to redirect the thrust vector.

Mission Design

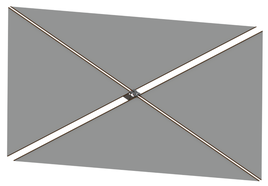

Figure 3: FeatherSail-3 model with deployed sails.

Initial Orbit:
- Altitude = 525 km
- Inclination = 72°

Final Orbit:
- Altitude = 650 km
- Inclination = 72°

FeatherSail-3's initial altitude is constrained by a requirement to deorbit within 25 years if the sails do not deploy. SRP will be used to raise FS3 to the required altitude.

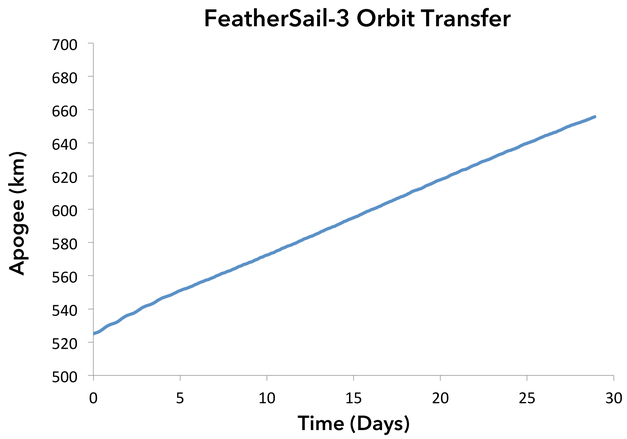

Figure 4: FeatherSail-3 transfer orbit apogee.

Predicted Deorbit Times:
- FASTSAT: 85 years
- FS3 and FASTSAT with 40 m^2 sail area: 1.1 years
- FS3 and FASTSAT with 20 m^2 sail area: 2.5 years
- FS3 and FASTSAT with 2.5 m^2 sail area: 25 years

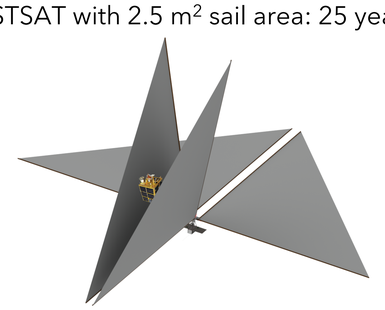

Figure 5: FeatherSail-3 with sails collapsed around FASTSAT.

Avionics

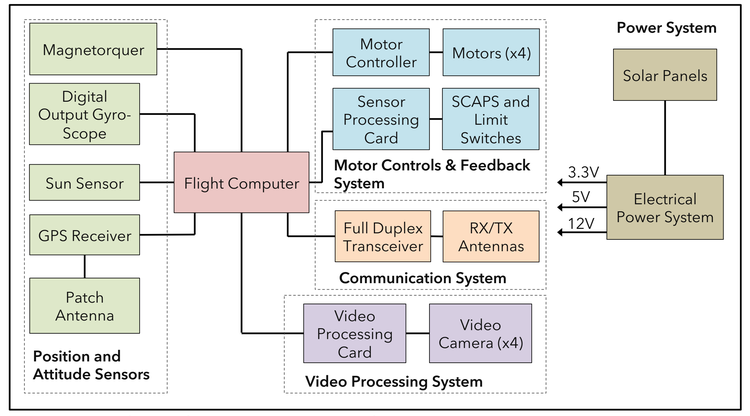

Figure 6: FeatherSail-3 avionics system diagram.

Flight Computer: nanoRTU™ 200
Motor Controller: Andrews Space Model 110 Motor Driver
Sail Position Sensing: Single Coil Absolute Position Sensor (SCAPS) consists of an excitation coil which induces a signal in a sensor coil. Magnitude and phase of signal represent an absolute position which will be used to determine sail angles.
Motors: (4x) FAULHABER Series 1226 brushless DC servomotor with planetary gearbox (256:1 reduction ratio, 300 mNm output torque)
Full Duplex Transceiver: VHF downlink/UHF uplink (150MHz transmission/420MHz receiving)
Video System: Texas Instruments video processing chip used to process four separate video signals to confirm sail deployment and autonomously track and rendezvous with FASTSAT.
Power System: Clyde Space Peak Power Tracker
Power Provided by Solar Panels: 16.75 W
Nominal Power Used: 7.63 W
Battery Capacity: 30 W-hr

Conclusion

- Developed FeatherSail-3 structural and mechanical model.
- Designed avionics and power systems for FeatherSail-3.
- Simulations show FeatherSail-3 is capable of overcoming aerodynamic drag and raising its orbit.
- Spacecraft will deorbit quickly after rendezvous and capture.

Acknowledgments: This work was supported by the NASA Marshall Space Flight Center Robotics Academy and the Alabama, Georgia, and Maine Space Grant Consortia. The authors would like to thank our mentor Dean Alhorn (ES32) for his help and guidance.